Precision Photometric Redshifts for Cosmology

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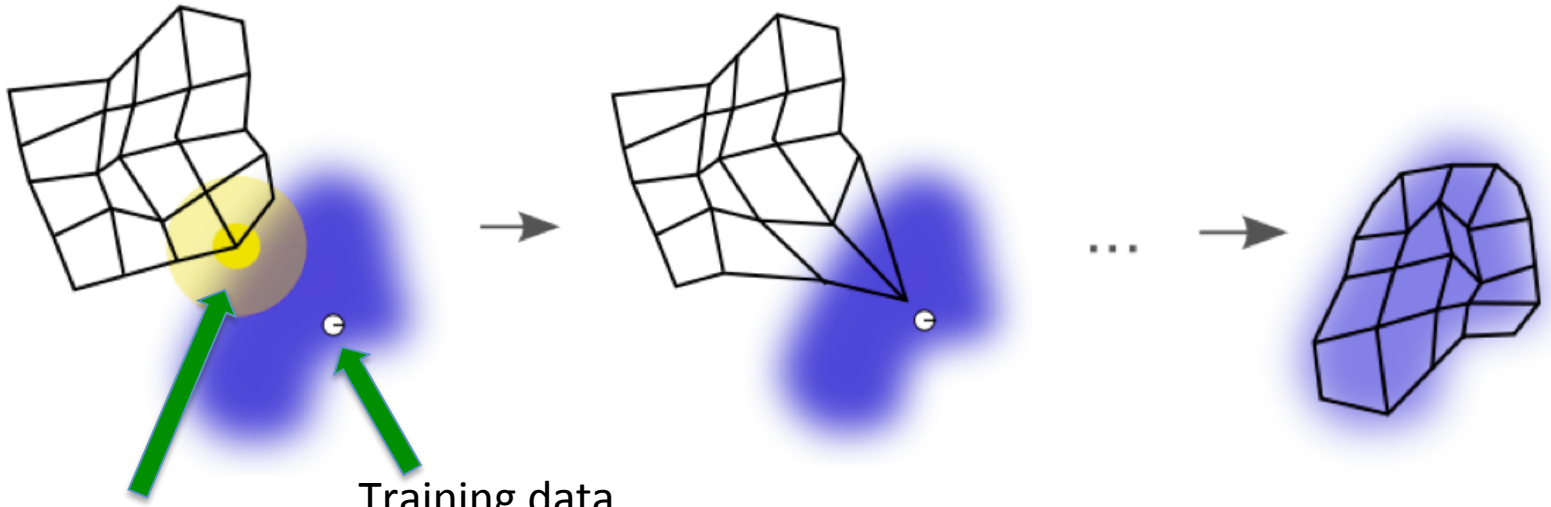
Goal

- Develop an optimal spectroscopic calibration strategy for WFIRST
  - Photo-z is measured from colors
  - We do not care about individual objects
  - Need redshift distributions for well defined samples
- Use machine learning to map the color space with an optimal grid
  - Ensure the spectroscopy represents the colors
- Already being developed for Euclid
  - Apply and extend this to WFIRST

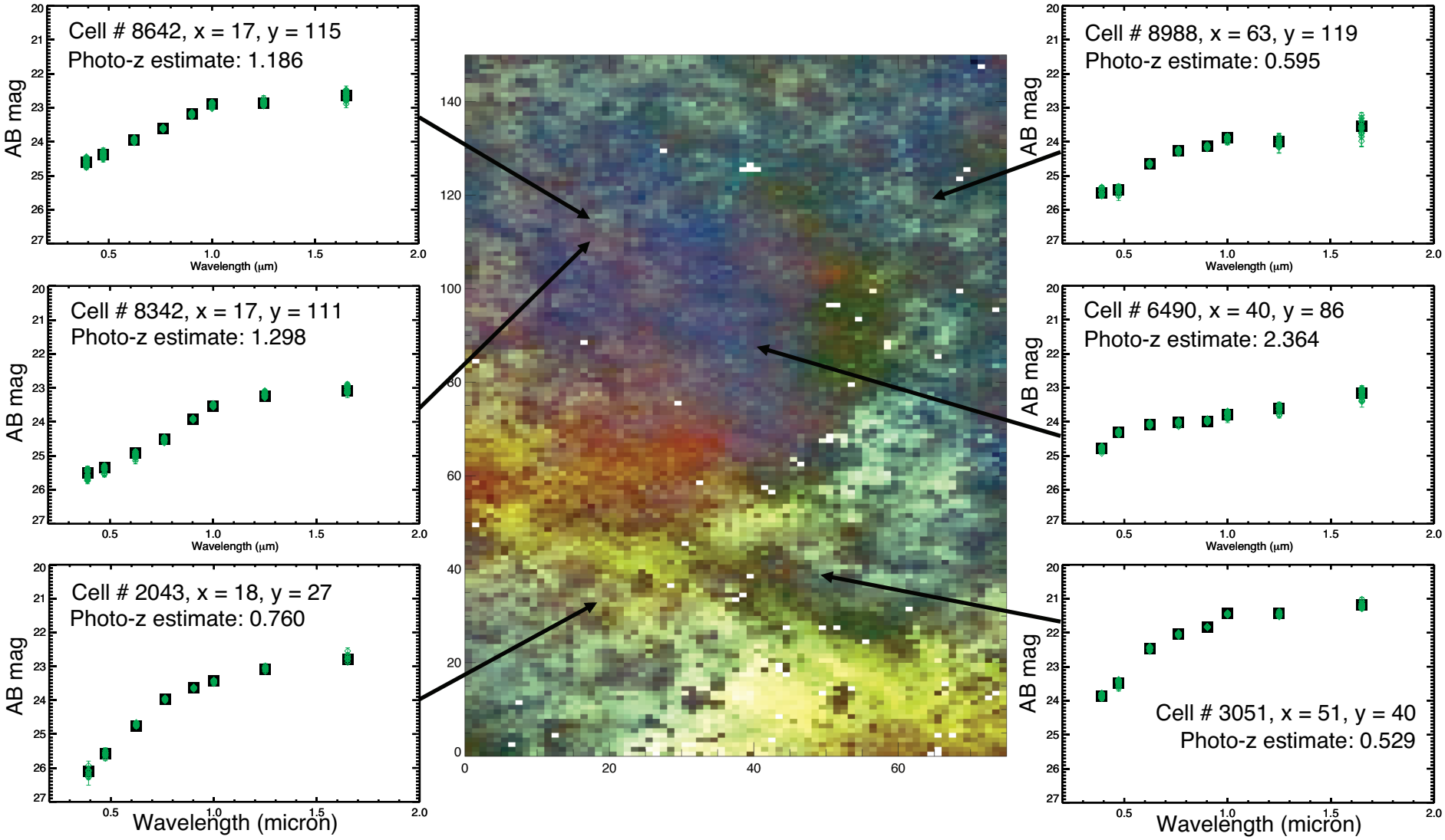
SOM Method

Self Organizing Maps (SOM): an unsupervised neural network method of mapping topology



1. Initialized map is presented with training data, i.e. the colors of one galaxy from the overall sample.
2. Map moves towards training data, with the closest cells being most affected.
3. Process repeats many times with samples drawn from training set until the map approximates the data distribution well.

SOM Method

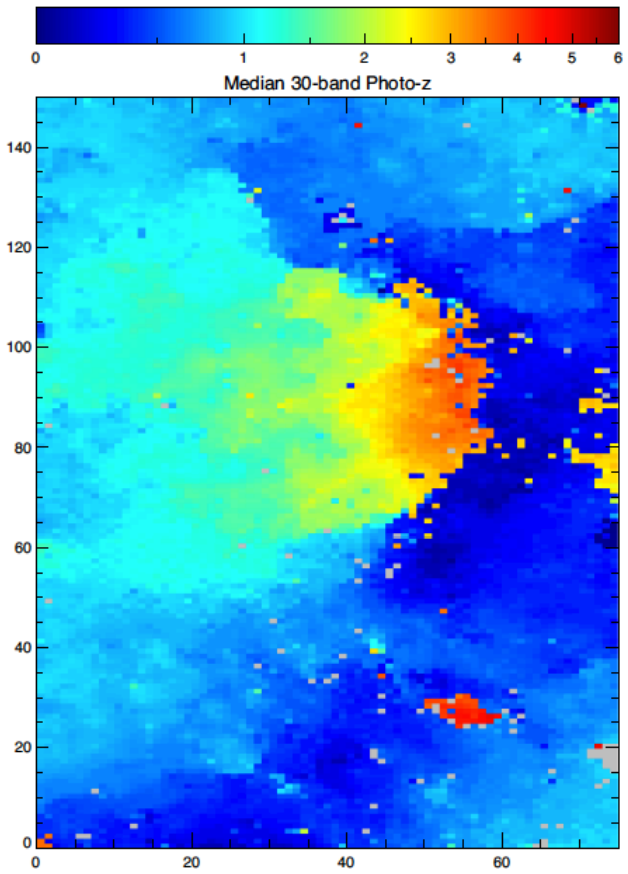


Masters et al. 2015

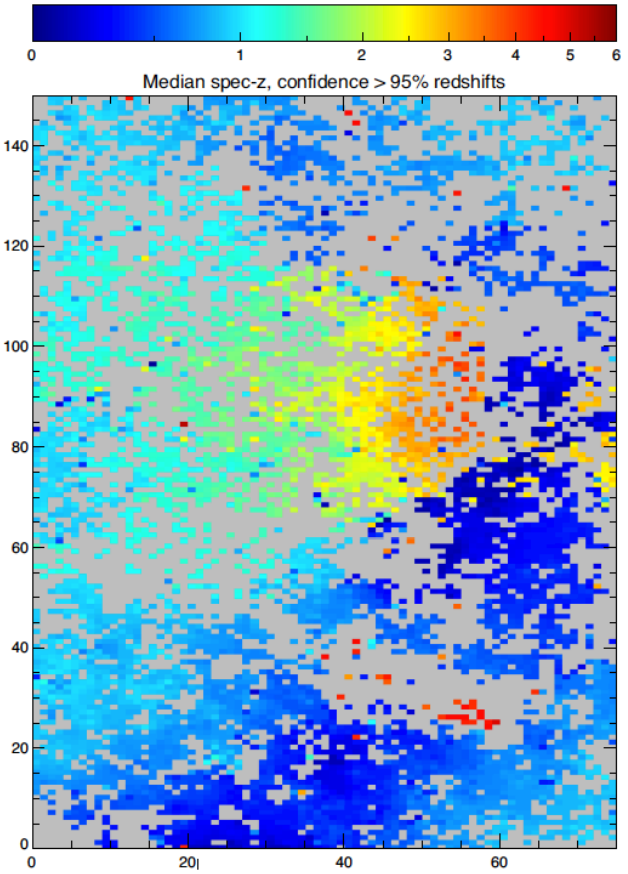
SOM Method

- Can visualize the 7-dimentional color data
- Test if the analytic model fits
- Test where the data driven model is valid
- Target grey areas with spectroscopy

Analytic (Template) Model



Data (spectra) Driven Model

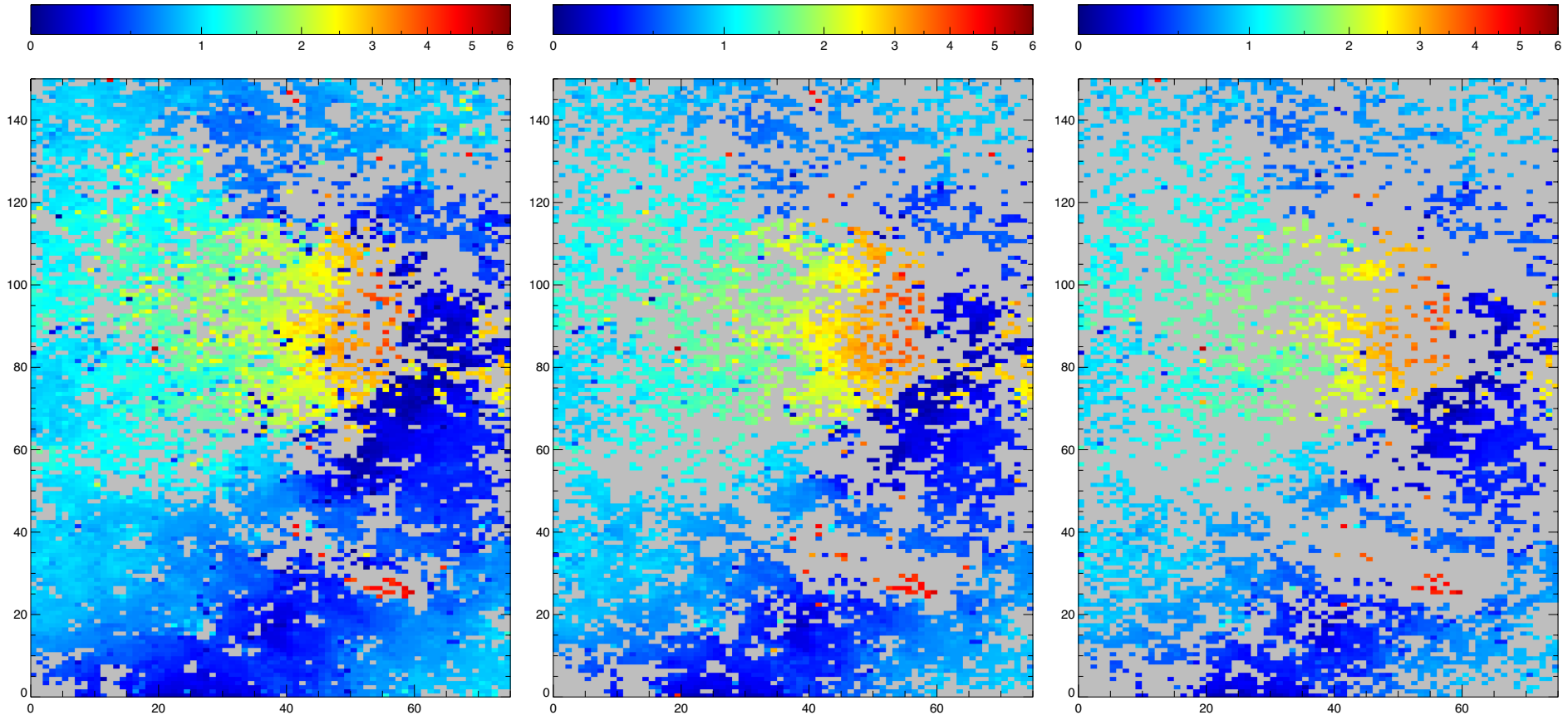


Spec-z's across the shallower *Euclid* map at different confidence levels

Conf. ≥ 2 redshifts
31% un-sampled

Conf. ≥ 3 redshifts
51% un-sampled

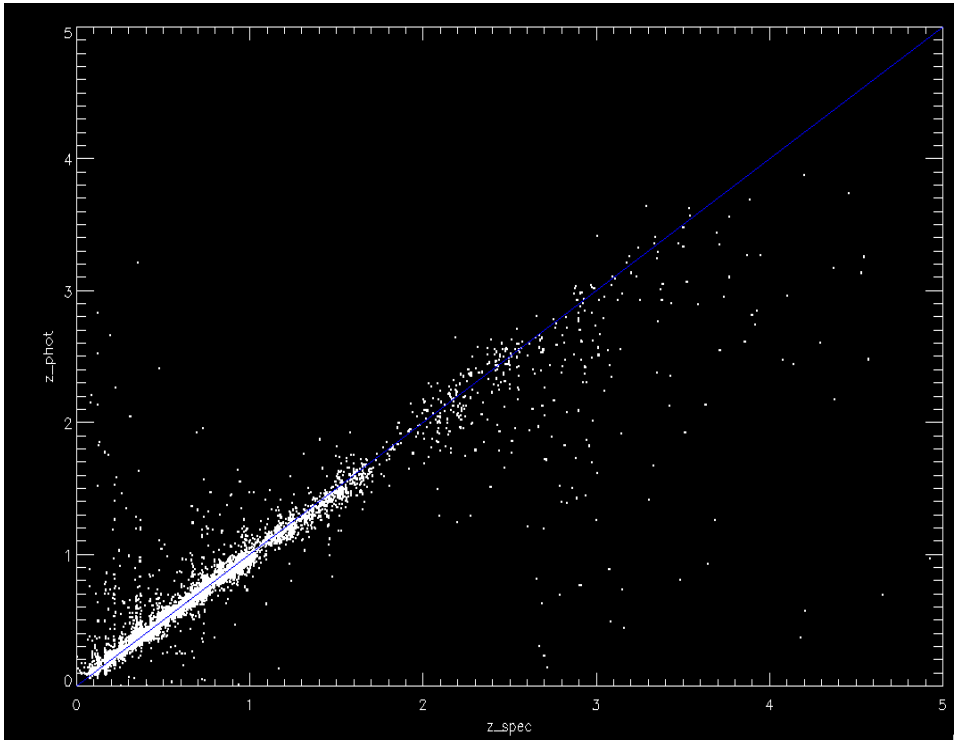
Conf. = 4 redshifts
64% un-sampled



At low confidence there appear to be very few Unknown-Unknowns. Main problem is getting high-confidence redshifts.

Preliminary test of SOM calibration

- Very preliminary test
  - Use median photo-z + existing spec-z
    - Ones shown here not used for calibration
  - Using only u,g,r,I,z,Y,J,H photometry
  - Monte-Carlo photometric errors of objects onto SOM
- Outlier fraction 1.5%
- Sigma_NMAD=0.02
- Bias = 0.004
- Many problems with this test
  - No interpolation
  - Not enough spec-z
  - Did not use full PDF
- Overall very promising
- Have also used SOM as a prior on SED fitting
  - Significantly improved results

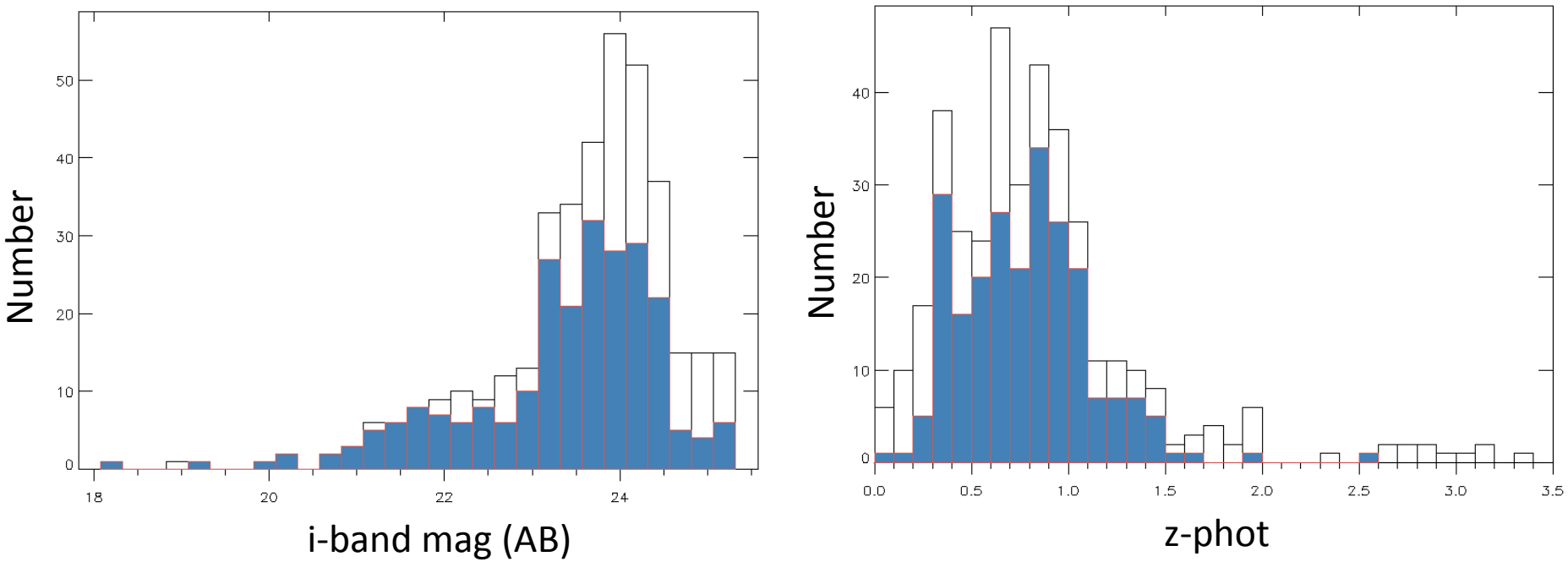


The Keck Complete Calibration of the Color-Redshift Relation (C3R2) Survey

- Sustained effort to map out the color-redshift relation of galaxies expected in the Euclid weak lensing sample (subset of WFIRST sample)
- 10 nights from NASA (5 each in 2016B and 2017B) as a Key Strategic Mission Support (KSMS) Proposal (PI D. Stern)
- 5 nights from Caltech in 2016A (PI J. Cohen), will re-apply
- Use Keck DEIMOS/MOSFIRE/LRIS multislit spectrometers to systematically map the color-redshift relation
- Optimal instrument and exposure time for targets are estimated based on SED, photo-z, magnitude, and existing spectra
- Currently have observed 4 nights (3 nights DEIMOS, 1 night MOSFIRE) with good conditions, ~500 high quality redshifts

Redshift results from Dec. 13, 2015 run

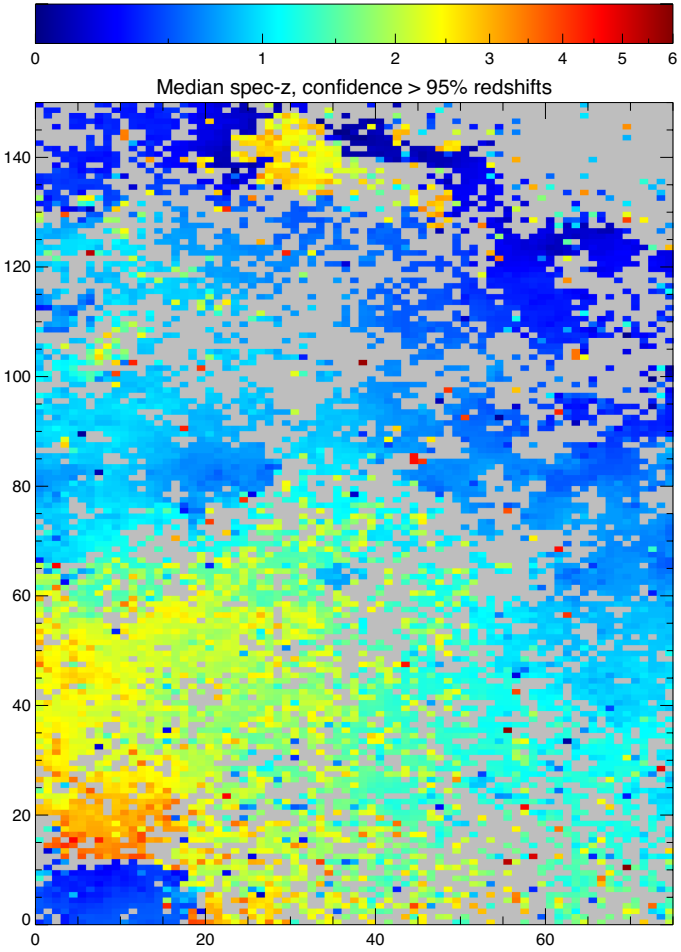
Redshift success as a function of magnitude and z-phot



- Total of 383 spectra taken with DEIMOS, with success rate of ~63%
- Success rate not a strong function of galaxy magnitude or redshift
- Most failures were "expected", objects too faint or at wrong redshift
- Importantly, we can keep track of where and why in parameter space we fail

Preliminary WFIRST SOM

- Based on SPLASH data, Higher-D
  - U,g,r,I,z,Y,J,H,K,ch1,ch2
- Similar to EUCLID SOM
  - Larger fraction of cells do not have spec-z at high-confidence
- Many of the cells that do have spec-z have fainter median mag
  - Need to test for “conformity” of fainter objects compared to brighter ones
- Will use CANDELS data for WFIRST like SOM in near future
  - How does volume of galaxy color space expand as we move to fainter magnitudes?
- If the volume of color space increases rapidly at faint magnitudes, the problem is harder
  - Need to quantify how to to expand SOM points

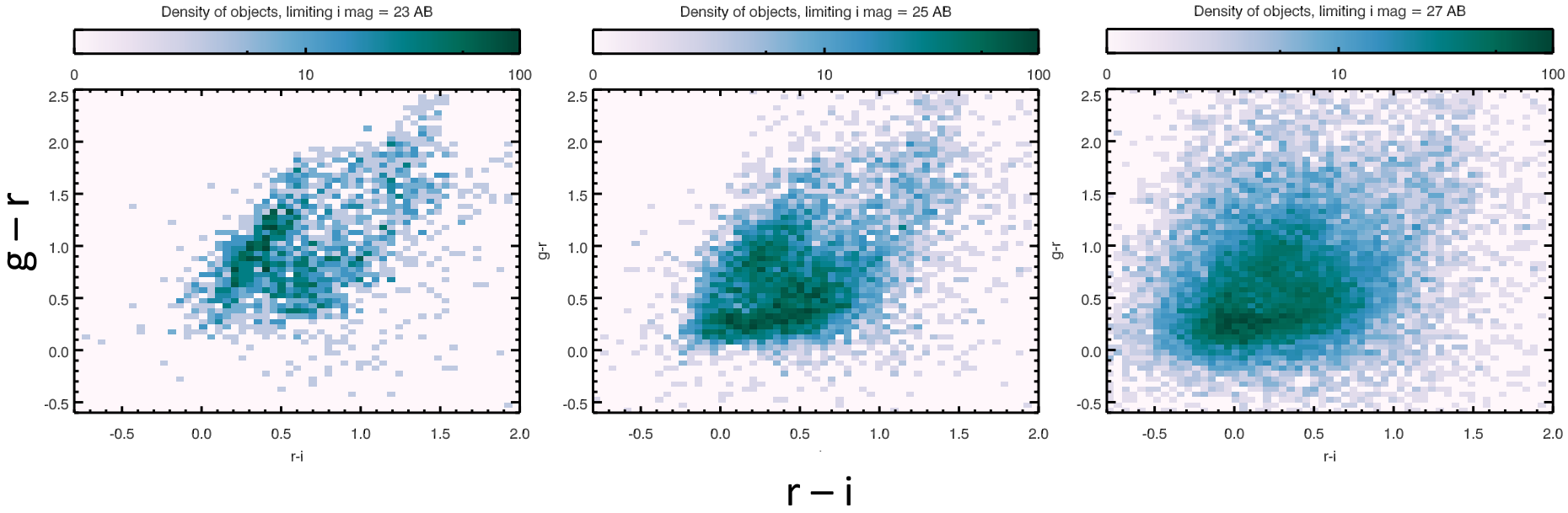


Challenge for WFIRST calibration: Growth of galaxy multi-color space with depth

i mag < 23 (AB)

i mag < 25 (AB)

i mag < 27 (AB)



- Distribution of galaxies in multi-color space grows significantly as the depth increases
- More spectra are needed to fully explore the space
- Moreover, the spectra become very challenging to obtain
- Need to check against lending cuts

Planned Milestones

- June 2015 - Collect Photometry
- July 2015 – Clean training sample
- Dec 2015 – Create preliminary map
- March 2016 – Finish map testing
- June 2016 – Collect and validate existing spectra
- Aug 2016 – Compare photo-z and spec-z map, determine spectroscopic needs
- Sept 2016 – Determine final metric for WFIRST spectroscopy
- Feb 2016 – June 2017 Collect new spectra following strategy
- June 2017 – Compare with new spectra

Actual Milestones

- June 2015 - Collect Photometry
- July 2015 – Clean training sample
- Aug 2016 -> Aug 2015 – Compare photo-z and spec-z map, determine spectroscopic needs (Ongoing)
- Dec 2015 – Create preliminary map
- Feb 2016 -> Dec 2015 – June 2017 Collect new spectra following strategy
- June 2017 -> Jan 2015 – Test new spectra (Ongoing)
- March 2016 -> April 2016 – Finish map testing, moved to allow for analysis of new spectra
- June 2016 -> July 2016 – Collect and validate existing 1d/2d spectra, moved to co-encode with Euclid database development
- Sept 2016 – Determine final metric for WFIRST spectroscopy
- Oct 2016 -> June 2017 – Determine if fainter WFIRST objects are "conformal" with brighter objects

Conclusions

- SOM method appears to be working
  - Significantly improves photo-z
  - Accurately predicts Galaxy types and spectra needed
- Started obtaining spectra for WFIRST/Euclid
  - Just (Monday) completed first 4 nights of Keck
  - Meeting expected metrics
- Need to quantify how to adjust SOM for WFIRST
  - Bigger color volume how many SOM cells needed?
  - What to do with fainter cells of same color